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Great Basin Integrated Landscape Monitoring Pilot
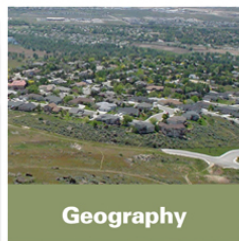
Project— Draft Project Plan

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U.S. Department of the Interior
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Great Basin Integrated Landscape Monitoring Project

Draft Project Plan

Executive Summary

This project plan describes the approach and first-year results of the Great Basin Integrated Landscape Monitoring Project (GBILM), an interdisciplinary effort to address landscape-level monitoring issues in the Great Basin. It is one of four pilots that were selected to implement a USGS science thrust on Integrated Landscape Monitoring. The GBILM pilot is focused on reconciling local, site-specific actions and natural events with landscape-scale processes and functions in an effort to provide a monitoring capability at the landscape scale. Specifically, the goal of the GBILM is to develop and test a landscape-level monitoring approach in the Great Basin which integrates USGS disciplines, addresses priority partner agency management questions, utilizes existing monitoring data, evaluates change at the landscape scale, and contributes to development of landscape monitoring strategies.

The GBILM organized an interdisciplinary team of scientists and managers that included representation from all U.S. Geological Survey disciplines and incorporated stakeholder representation from the Bureau of Land Management, National Park Service, and Environmental Protection Agency. To develop an understanding of the Great Basin ecosystem and the key ecological components and drivers in the system, the GBILM initiated development of hierarchical conceptual ecosystem models. These models provide an overarching characterization of landscape function, identify key ecological processes and services, guide development and prioritization of the most pressing resource management questions, inform regional monitoring strategy development, and identify critical gaps in our understanding of ecosystem function. These conceptual models were used to identify ecosystem drivers, both natural and anthropogenic, that are the primary causes of change in Great Basin ecosystems.

The GBILM is focusing on three priority ecosystem drivers to test the approach of developing management questions and analyzing existing data to assess, predict and monitor landscape change in the Great Basin. The three drivers identified for extended evaluation are groundwater extraction in the wet system, and wildfire-invasive species interactions and land treatments in the dry system. These have been selected based on their importance to managers and communities, ecological significance, and availability of data. The next step in the process was the identification and prioritization of management questions associated with each of the selected drivers. These questions were prioritized on their importance to resource management and the availability of existing monitoring data to address the questions. The GBILM then developed example projects to address selected management questions as a mechanism to demonstrate data analysis and prediction of landscape change from existing data sources.

Three projects are being initiated to test the concept of using site-specific information to address management questions and monitoring needs at the landscape-scale. These projects include: 1) Predicting locations of phreatophytic communities and identify areas at risk from increased water withdrawals; 2) Using spatial patterns of fire and landscape characteristics to evaluate the effects of invaders on fire regimes; and 3) Assessing and predicting effects of land treatments at various scales on wildlife habitat.

These projects will be the first steps towards predicting landscape changes based on analysis of existing data and developing a landscape-scale monitoring approach for the Great Basin. Future

efforts will include expanding the process to address additional drivers, developing monitoring methodologies, and testing monitoring approaches.

Building partnerships with management agencies and other partners is essential for assuring the GBILM's relevance, usefulness, and long-term success. Toward this outcome, the GBILM is seeking partner agency and stakeholder input throughout the project. Their perspectives are especially critical to keep the project focused on priority management questions and landscape-scale monitoring needs.

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Introduction

This project plan describes the approach and outcomes of the Great Basin Integrated Landscape Monitoring Project (GBILM), an interdisciplinary effort to address landscape-level monitoring issues in the Great Basin. This effort is one of four pilots that were selected to implement a U.S. Geological Survey (USGS) Science Thrust on Integrated Landscape Monitoring. The four pilot areas include Northern Prairies, Lower Mississippi Valley, Puget Sound, and Great Basin. The integrated monitoring pilots were initiated to increase collaboration, summarize and synthesize existing environmental information, foster communications among scientists and stakeholders, and jointly set priorities for research and monitoring needs on the landscape. The primary goal of this science thrust is to observe, understand, and predict landscape change and its implications on natural resources at multiple spatial and temporal scales to address priority natural resource management and policy issues.

Contemporary land and resource managers are challenged to achieve multiple, sometimes contradictory, agency mandates in the context of a changing environment. They are faced with overseeing resource extraction and production of goods and services while regional and global stressors (e.g., invasive plants, climate change) complicate the systems they manage. For management activities to be successful, cost-effective, and sustainable while conserving limited resources, managers need to know which resources are at greatest risk of loss which resources function as "keystones," which resources are most sensitive to change, how resources and ecologic processes are predicted to change, and the direct and indirect effects of management actions. Despite most management actions being taken locally, a landscape perspective is necessary because the managed resources are subject to regional and global processes, stressors and changes, and the cumulative effects of individual management actions.

The Great Basin provides an opportunity to test concepts and develop the tools needed to analyze monitoring data and understand change at multiple scales, and ultimately provide a predictive capability of landscape change. The GBILM pilot is focused on reconciling local, site-specific actions and natural events with landscape-scale processes and functions in an effort to provide a monitoring capability at the landscape scale. Specifically, the goal of the GBILM is to develop and test a landscape-level monitoring approach in the Great Basin which integrates USGS disciplines, addresses priority partner agency management questions, utilizes existing monitoring data, evaluates change at multiple scales, and contributes to development of landscape monitoring strategies.

Description of the Great Basin

The Great Basin includes over 111 million acres of lands in five western states, including California, Idaho, Nevada, Oregon, and Utah (Figure 1). About 78 percent of these lands are under public ownership, and the majority of the public lands are managed by the Bureau of Land Management (BLM). The Basin forms a wedge between the Sierra Nevada and Rocky Mountains. Bounded to the north by the Columbia Plateau and Snake River Plain and to the south by the Mojave Desert, the most notable feature of the region is its internally draining hydrology. For this project, we define the Great Basin as being encompassed by Omernik's (1987) Northern and Central Basin and Range Provinces (Figure 1).

The Great Basin is characterized by semi-arid landscapes and is a mosaic of diverse shrublands, grasslands, and montane forests incised with rare, critical riparian corridors and aquatic resources.
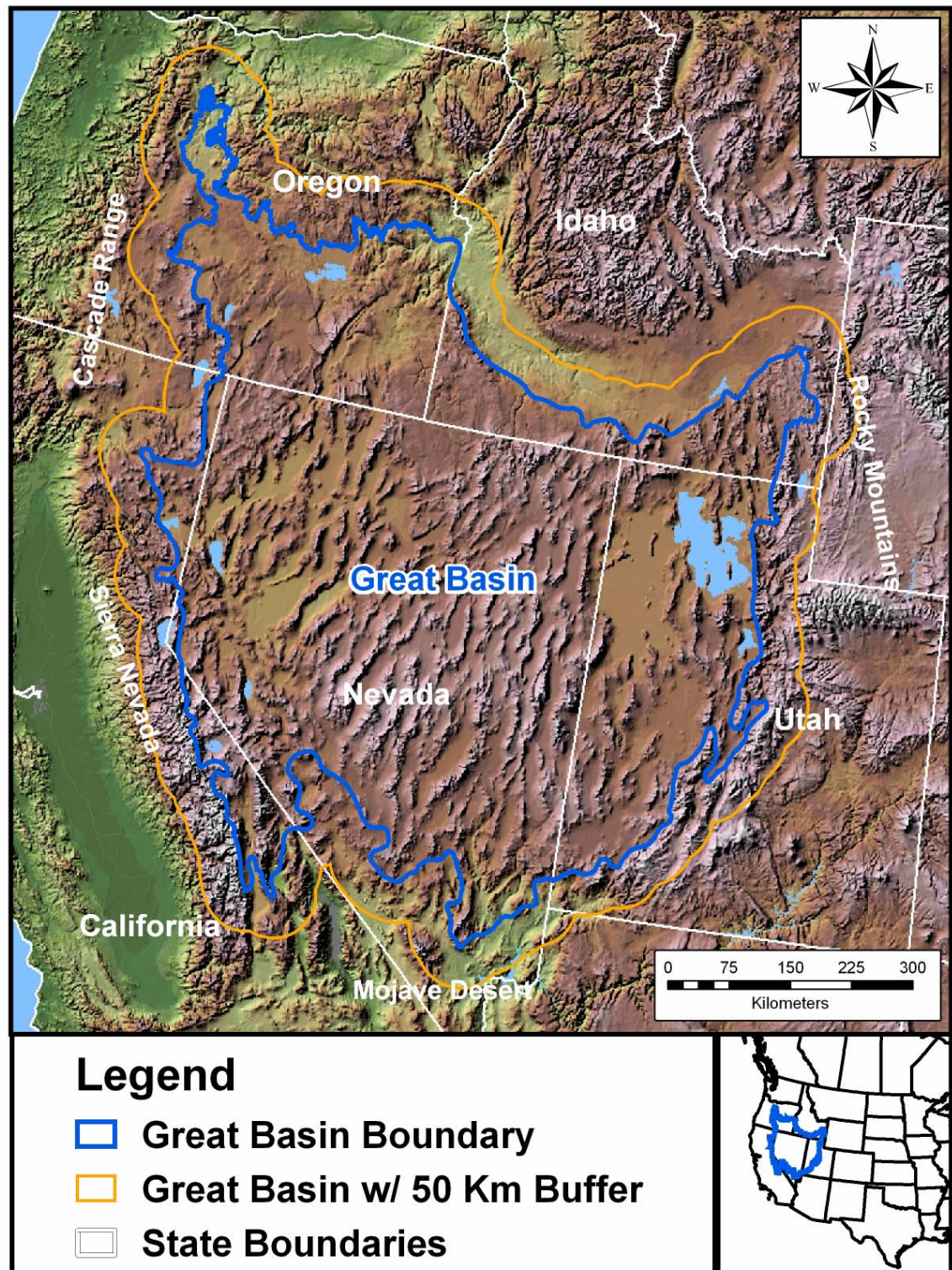
Figure 1. The Great Basin, an area defined by ecosystem boundaries of the northern and central Basin and Range provinces (Omernik 1987) plus a buffer so as to include pressures from lands adjacent to the Great Basin. The base map is shown in shaded relief to highlight the mountainous nature of the Great Basin.

Although often perceived as a "desert wasteland," it is one of the most diverse ecoregions in its number of endemic native plants and animals, and has a growing list of federal- and state-listed species and species of concern (e.g., Virgin River chub, Owen's Valley vole, greater sage-grouse, pygmy rabbit, and Brewer's sparrow). For example, the Great Basin contains over 130 endemic plant species or subspecies, 95 of which are imperiled. A driver of this high endemism is the patchy nature of many habitat types and the fluidity of patch connectivity across the landscape over geological time. Within 20 kilometers, a single basin-range unit can host environments that range from treeless alpine bogs and rocky slopes to montane coniferous forests, diverse mountain shrublands, pygmy woodlands of pinyon pine or juniper, lower slopes of sagebrush and grasses, lake shores, barren sand dunes, and playas.

While much of the Great Basin is remote and rural, it also includes some rapidly growing cities and urban areas, and an increasing demand on natural resources. Major land uses, including urban expansion, road development, surface and ground water development, mineral and energy extraction, livestock grazing, and agriculture, are having increasing impacts on the composition, structure, and function of the landscape. Wildfires have burned over 25 percent of these lands in the past decade, leading to accelerated invasion of non-native species, reducing rangeland health and productivity, and affecting species at risk. The fire regime in the Great Basin has typical been on a 70-100 year cycle, but has now been altered to a 7-10 year cycle. These changes in the fire cycles are leading to large-scale replacement of native land cover with exotic annual grasses, which perpetuates the shortened fire cycles. Extensive drought conditions and growing demands on surface and groundwater have a substantial impact on the ecosystem functions and the human populations' dependent upon them. Today, the consequences of expanding land uses, invasion of exotic species, and altered disturbance regimes have affected virtually the entire Basin. Changes in the Great Basin have resulted in its designation as one of the most endangered ecosystems in North America.

Project Development Process

The Integrated Landscape Monitoring Science Thrust incorporated four pilots as a mechanism to test different approaches for implementing landscape-scale monitoring. GBILM took the approach of adopting a set of science and institutional goals. The science goals focused on developing and testing an interdisciplinary approach to detect landscape change across the Great Basin whereas the institutional goals involved developing and documenting an approach to guide future integrated landscape-scale monitoring efforts. To achieve our institutional goals we developed a staged approach to building a monitoring program and documented our steps in the hopes of creating a process that could be applied to landscape monitoring in other ecosystems.

To achieve our science goal we initiated the staged approach to understand the ecosystem processes in the Great Basin and address priority resource monitoring needs. Preliminary stages included formulating an interdisciplinary team, developing a communication infrastructure (http://my.usgs.gov), identifying critical natural resource issues in the region, demonstrating ongoing USGS research programs that address these issues, and defining our agency's science capabilities in the Basin.

With this basic understanding of the system firmly documented, we proceeded to define components and processes of Great Basin ecosystems that were most approachable by developing conceptual ecosystem models, identifying priority system drivers, and defining and prioritizing important management and monitoring questions (each described in detail below). The GBILM team agreed that, given the size of the Great Basin, the number of priority resource issues, and the funding and staffing limitations associated with the pilot, we should initially focus on existing monitoring data rather than initiating new data collection efforts. Land and resource management agencies regularly collect site specific monitoring data to evaluate the success or failure of their actions, but often they do not have the analytical tools or organizational structure to evaluate the information at the landscape

scale. We agreed that existing data that addressed high priority management questions could contribute to hypothesis development if it were compiled and cataloged across jurisdictional boundaries. While management questions were being prioritized and selected, we also identified a short list of projects that could be completed using existing monitoring data. These projects (see below) will be used to test whether existing monitoring data can be used to identify trends and causes of change at the landscape scale. While conducting these projects, we will evaluate the quality of the data, identify data gaps, and work with partner agencies to refine monitoring strategies, improve data quality, and share analytical abilities across disciplines and scales.

Future (FY2008 and beyond) steps will include multivariate, multi-stressor analysis of landscape trend with subsequent development and testing of predictive models; development of a comprehensive monitoring strategy for the region with full integration of existing monitoring efforts and strategies including the BLM's Assessment, Inventory and Monitoring (AIM) programs, and National Park Service's (NPS) Inventory and Monitoring (I&M) Program.

Conceptual Models

In general, ecological models express a progression of scientific thought that starts with determining key ecological components, and ends with a summary of the causal ordering and relationships among them. Conceptual models are specific tools for planning, communicating, and prioritizing these ecological components and relationships. Conceptual models are a necessary part of ecological monitoring because they focus and define the scope of the monitoring program; however, they are not an end product in and of themselves. The GBILM pilot project created a set of conceptual ecosystem models to develop an overarching characterization of landscape function, identify key ecological processes and services, guide development and prioritization of the most pressing resource management questions, inform regional monitoring strategy development, and identify critical gaps in our understanding of ecosystem function. This section describes: 1) the process used to develop the conceptual models, 2) the framework for ecosystem models, and 3) draft sub-models to illustrate our approach of scaling from a coarse-scale model to system-specific models. The Great Basin conceptual models are more fully described in a conceptual model report. We expect to create a cumulative impacts model as a first step toward developing predictive capabilities for Great Basin landscape change.

We identified critical ecosystem drivers (see below) and developed graphical and narrative conceptual models describing ecosystem components and function. We rapidly turned to the significance of water to deserts of the Great Basin as a way to distinguish between precipitation-event-driven systems ('dry' systems) and surface- and groundwater systems ('wet' systems), which respond to precipitation at longer time scales. The wet and dry systems are described in a hierarchy of models, with each model tier successively more focused on specific ecological habitats and processes (Figure 2). We constructed the highest-order "framework model" to coarsely describe interactions among the Wet and Dry response systems and two primary driver-contributing systems: Atmosphere and Human/Social systems (Figure 3).

We then constructed 'system models' for each of these four coarse-scale systems in order to scale down from the Framework model. At this stage, we identified subsystem components for the Wet and Dry Systems that are most significant in a management context. We identified riverine/riparian, groundwater dominated wetland and spring, fresh water lake and marsh, saline lake and marsh, salt desert steppe, sagebrush steppe, pinyon-juniper woodland, aspen forest, conifer forest, and alpine systems as being relatively well defined ecological units and also relevant to land managers. We listed these components in the framework model (Figure 3) and detailed more

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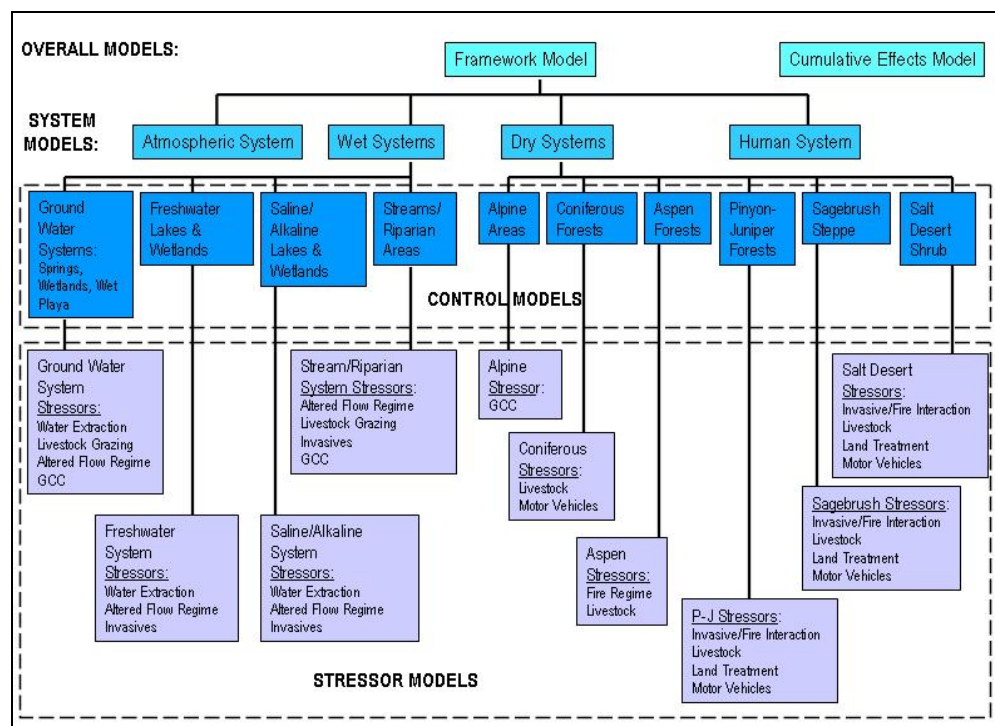**Figure 2.** Hierarchy of conceptual models to explain and justify the choice of monitoring questions and indicators. (GCC = Global Climate Change).
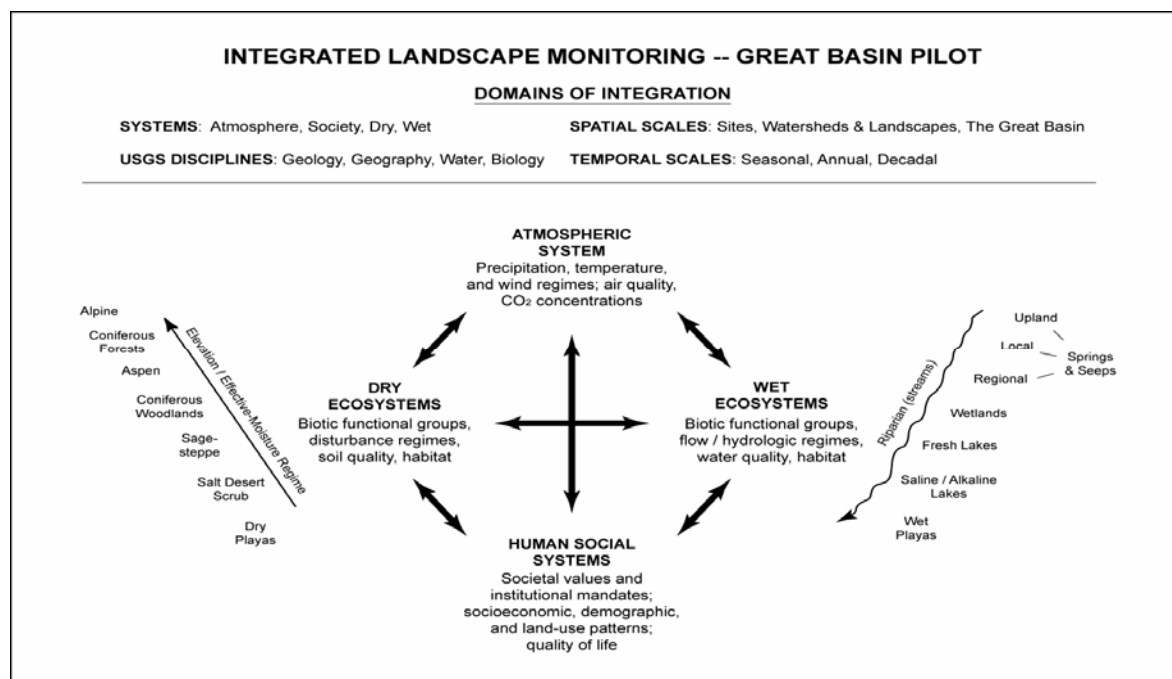

Figure 3. Diagram illustrating the overall conceptual framework for the GBILM pilot project.
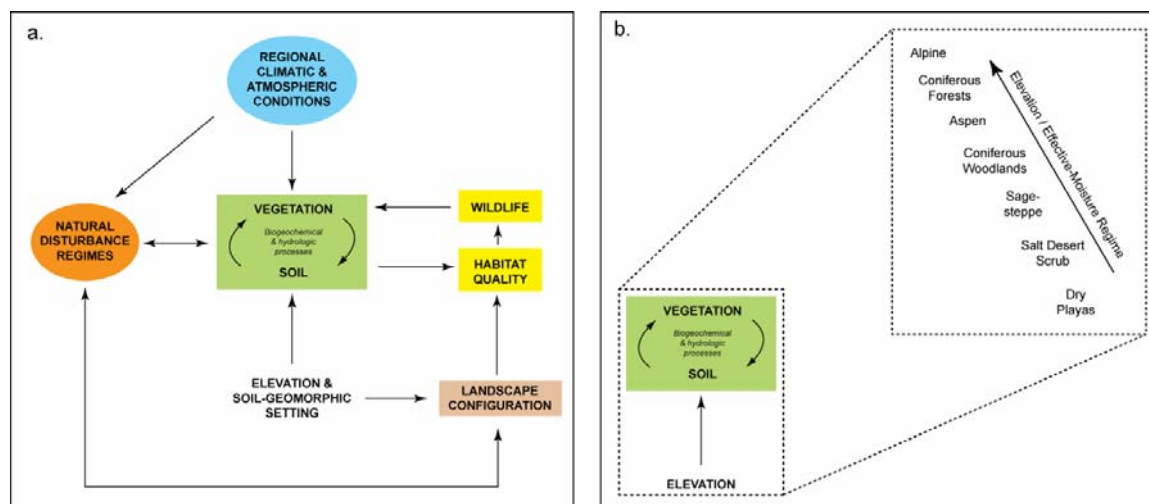
Figure 4. Dry system model describing fundamental components and processes of Great Basin systems driven by soil moisture.

specific spatial and process relationships among the components in second-tier system models (Figure 4). We also prepared system models for the Atmospheric and Human/Social Systems but decided that more detailed development of these models was not an immediate priority of the GBILM.

The team then prepared third and fourth tier models (called "control" and "stressor" models) for two focal systems: sagebrush steppe and stream/riparian. We decided that these example models would: 1) serve as stand-alone models for the respective subsystems, 2) provide "straw men" for further iterative critique and review of our process, and 3) be representative examples for modeling the other key subsystems. As Figure 5 illustrates, scaling down the models shifts the focus from place-based components to resource and process components. Figure 6 shows one stressor submodel based on the sage steppe control model.

All of the conceptual models developed for the GBILM are designed to be adaptive constructs that can be modified based on insights gained during the development process and ongoing research. Therefore, we included a section for "Knowledge Gaps" for each sub-system that outlines known shortcomings and postulates approaches to overcome current information gaps.

We recognize that we need to integrate the responses of the subsystems across the scale of the Great Basin in order to capture the cumulative effects of patch dynamics on the holistic ecosystem, including, for example, the proportional amount and distribution of habitat types, and the soil and climate constraints on ecosystem potential. Therefore, a final critical step of the conceptual modeling process will be to develop a cumulative effects model that integrates spatial and temporal scales as well as the synergistic effects of multiple drivers on a given system or systems.

Ecosystem Drivers and Stressors

Ecosystem drivers are any natural or human-induced factor that directly or indirectly causes a change in an ecosystem. For the GBILM, we focus on ecosystem drivers, both natural and anthropogenic, that are the primary causes of change in Great Basin ecosystems. The distinction between natural and anthropogenic drivers is somewhat artificial, and sometimes difficult to define. Natural drivers tend to be the consequence of periodic processes that are typically in a state of equilibrium in the absence of excessive human pressures. By comparison, anthropogenic drivers
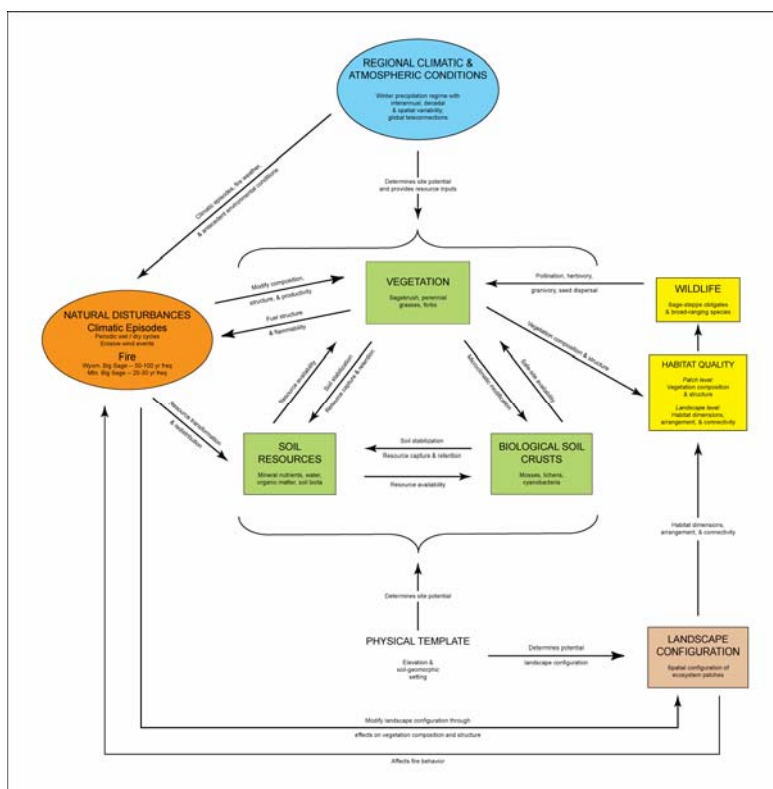
Figure 5. Conceptual model illustrating key structural components (colored rectangles) and functional relations (arrows) of Great Basin sagebrush steppe ecosystems, excluding major effects of human activities. Colored ovals represent natural drivers of temporal variability and change. (Adapted from Miller 2005.)
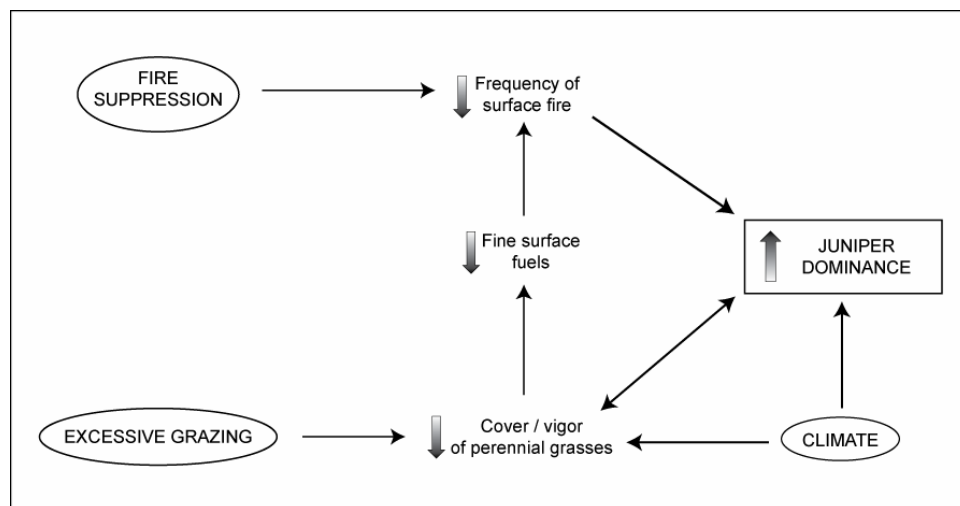
Figure 6. Conceptual model illustrating processes by which multiple drivers and stressors (ovals) can lead to increasing dominance of junipers in sagebrush steppe ecosystems (adapted from Miller 2005). These and other confounding drivers may also move the sagebrush steppe ecosystem toward dominance by annual grasses.

result from human activities, tend to be directional, rather than cyclical, and may result in losses in biodiversity or functional integrity.

The GBILM developed a comprehensive list of the primary drivers in the Great Basin (Table 1). These drivers can be incorporated into conceptual models to help explain the impact that natural and anthropogenic forces have on each focal system. We approached this task by introducing system drivers at the control model level (Figure 5) and further refining focus on the drivers in stressor models (Figure 6) where each model details the linkages among a subset of drivers, the ecosystem components and processes they affect, and potential outcomes of the drivers. Drivers are almost always multiple and interactive, so that a one-to-one linkage between a particular driver and a particular change in ecosystems rarely exists. As a result, multiple stressor models are needed to address interacting drivers.

Table 1. Major ecosystem drivers in the Great Basin.

Agriculture	Light pollution
Altered flow regimes	Linear infrastructure
Atmospheric Pollution/deposition	Livestock grazing
Channelization	Military land use
Climate change	Motorized vehicle access
Climate variability	Roads
Economic and political	Particulates (airborne and deposited)
Erosion	Pathogens
Fire acceleration	Recreation
Fire regime	Resource extraction
Fire suppression	Sound pollution
Insects and disease	Urban-exurbanization
Invasive exotic plants	Water extraction/irrigation
Invasive exotic animals	Water impoundment/diversion
Land use - cover change	Water pollution
Legal mandates	

The stressor models and the drivers and system elements they illustrate act as hypothesis generators allowing the GBILM team to propose relevant management questions. In practice, questions and alternative hypotheses for ecosystem function arose as we developed both driver priorities and control and stressor models. As we worked through these exercises, it became apparent that the system drivers and ecosystem processes that GBILM could address through management question generation were only a small subset of the entire suite of natural resource issues that managers are responsible for. Therefore, prioritizing the drivers and linking them to specific ecosystem components in the conceptual models allowed us to focus our primary management questions on those aspects of the system that were most in need of answers due to their temporal, spatial, systemic, and/or social urgency. The iterative process of prioritizing and reevaluating ecosystem drivers and vetting the outcomes before land management agency representatives, led the GBILM team to identify some of the highest priority drivers. These drivers and system justifications are described below. We recognize that even this list may be too ambitious, and that continuing stakeholder input may change the priorities.

Wet Systems

- Water Extraction— Withdrawal of groundwater is widespread and accelerating in the Great Basin, both for agriculture and urban use. Groundwater withdrawal lowers water tables due to low recharge rates, and the lowered water table leads to loss of springs and wetlands.

- Flow Regime— Diversion of streams for irrigation, disruption of stream flow by roads levees, channel changes for flood control or other reasons, and climate change resulting in changing precipitation and altered snowmelt patterns all contribute to altered flow regime and stream function.

- Livestock Grazing— Virtually the entire Great Basin is subject to livestock grazing. Livestock trample stream banks and wetlands, altering riparian habitat and changing hydrologic function. In addition, livestock alter species composition and degrade water quality by nutrient loading.

- Invasive Exotics— Introduction of invasive aquatic species has altered virtually every water system in the Great Basin. For instance, sport fish have been introduced to nearly every stream, and invasive plants have altered the structure, function, and habitat value of many riparian and wetland systems.

- Climate Change and Variability— Global climate change and accompanying increased climate variability threatens to alter snowmelt periods, reduce water available for stream flow and lakes, and increase impacts from intense storms, such as floods.

Dry Systems

- Fire Regime— Altered fire regimes have caused significant changes in vegetation structure, associated ecosystem processes, and altered ground fuel amounts. Mediated by changes in vegetation structure, ecosystem-level consequences of altered fire regimes can include diminished hydrologic function and increased erosion rates, as well as increased ecosystem susceptibility to drought.

- Invasive Species-Fire Interaction— Introduction of Mediterranean annual grasses has led to infilling of inter-shrub spaces with highly combustible grass, increasing intensity and frequency of fire in shrub-lands of the Great Basin. Increased fire frequency alters natural fire cycles, promoting invasive grasslands over native shrubs, altering soil properties, and degrading wildlife habitat.

- Livestock Grazing— Grazing alters species composition, vegetation structure, and animal habitat through many mechanisms. Trampling by livestock destabilizes soils, alters hydrologic processes, and facilitates the establishment of invasive exotic plants.

- Land Treatments— Land treatments include management actions intended to change land conditions for management purposes, such as range or habitat improvements. Land treatments include post-fire stabilization and rehabilitation, crested wheatgrass and other introduced seedings, chained shrublands and woodlands, habitat restoration projects, and fuels reductions/treatments. These treatments cause vegetation change, affect soil stability and nutrient cycling, and alter wildlife habitat.

- Motor Vehicle Use/Road Development— Motor vehicles, used both on road and off, are potential vectors for invasive species and toxic contaminants, and effectively introduce refuse and accelerated human visitation. Off-road vehicle use promotes soil compaction, plant mortality, and erosion. Road corridors lead to habitat fragmentation and increased spread of invasive species.

- Climate Change and Variability— Increasing levels of atmospheric carbon dioxide, increasing soil and air temperatures, and altered precipitation patterns are likely to affect physiological processes and competitive relationships of vascular plants, nutrient cycles, hydrologic processes and disturbance regimes – all of which have the potential to greatly alter the structure and functioning of dryland ecosystems.

Using Examples to Demonstrate the Approach

Due to the number and complexity of the drivers and the untested nature of landscape monitoring in the Great Basin, we are focusing on three of the priority drivers to test the approach of developing management questions and analyzing existing data to assess, predict and monitor landscape change in the Great Basin. The three drivers identified for extended evaluation are groundwater extraction in the wet system, and wildfire-invasive interactions and land treatments in the dry system. These have been selected based on their importance to managers and communities, ecological significance, and availability of data.

We have developed brief proposals for each of these drivers to demonstrate analysis and prediction of landscape change from existing data sources (summarized below) (see appendix for proposals). Climate change and motorized vehicle use are also being considered as examples. All of these examples will be vetted with partner agencies to make sure GBILM is focusing on compelling management issues and providing results and products that are accessible and useful for resource managers.

Developing Questions

The foundation for the landscape monitoring program is the development of management questions which reflect compelling real-life needs of our management agency partners. They are important because they bring focus and relevance to our work and provide the basis for evaluating interactions among management actions, other environmental factors, and landscape change. Therefore, the first step in this process is to identify and prioritize management questions associated with each of the selected drivers. These questions then lead to study questions which will drive a line of assessment and inquiry about landscape-scale conditions and projected changes. To illustrate how this could be accomplished, the GBILM developed a hierarchy of management and study questions related to each of the prioritized drivers (see Appendix B for a full list). In this process, questions have been prioritized, not only on their importance to management, but also on whether data are available to support an example project. For each of the selected drivers, the list was eventually winnowed to focus on specific questions as the basis for assessment and prediction as well as monitoring applications (summarized in Table 2). These questions will be further reviewed and refined with partners to accurately reflect their needs.

Data Mining and Evaluation

This is the next step to follow after articulating management and monitoring questions. We are applying a data analytic approach to mine, analyze, and integrate monitoring and other data across spatial scales. As existing data sets are pulled together and assessed, we will gain information about data quality and comparability, data gaps, and additional monitoring needs. Identification of data quality deficiencies and data gaps will focus future data collection and additional studies. Each of the examples has identified the sources and types of data to be compiled. These vary from remotely sensed information and GIS layers to databases and site-specific vegetation information.

Data Analysis to Assess Status and Trend and Predict Change

Analysis of the existing data will produce landscape-scale assessments and add to our understanding of ecosystem processes and interactions related to the specific management and study

Table 2. Summary of three example projects, including management and study questions, the potential monitoring applications, and the proposed pilot project.

	Wet System / Water Extraction Driver	Dry System / Fire-Invasives Interaction Driver	Dry System / Land Treatments Driver
Management Questions	• How will increased water extraction impact phreatophytes? • Can phreatophytic communities serve as an indicator of impacted groundwater systems?	• How should land managers prioritize efforts to manage fire regimes to retain and restore desired plant communities? • What can managers do now to manage current and potential fire regimes?	• How are land treatments cumulatively influencing vegetation and wildlife? • How can land treatments be used to achieve multiple goals, including creation of wildlife habitat?
Study Questions	• Where are potential phreatophytic communities, and what are their landscape characteristics? • What are the effects of aquifer drawdown on phreatophytic communities? • How do groundwater systems operate and what is the natural envelop of variability? • What is the impact of anthropogenic stressors on ground-water? • What are the areal relationships between ground-water extraction sites and impacted vegetation communities? • How do lowered ground-water levels affect streamflow and surface-water availability?	• What are the recent patterns of fire regime variables? • How do patterns relate to landscape characteristics? • How do patterns compare with historic conditions? • Is there evidence for shifts in fire regimes due to exotic plants? • How may patterns and relationships respond to climate change?	• What land treatments have been used? • What are their characteristics? • Where on the landscape? • What is the effect of spatial properties and landscape position of land treatments on wildlife habitat? • How does climate change and anthropogenic stressors effect land treatment results?
Monitoring Applications	• Identify indicators of change in spring discharge and ground-water levels. • Develop methods to measure change in indicators.	• Develop best approaches and tools to monitor and predict fire regimes and associated vegetation change.	• Develop improved methods to evaluate treatment effectiveness. • Monitor effects of climate change and anthropogenic stressors on treatment results.
Proposed Pilot Project	Predict locations of phreatophytic communities and identify areas at risk from increased water withdrawals	Use spatial patterns of fire and landscape characteristics to evaluate the effects of invaders on fire regimes	Assess and predict effects of land treatments at various scales on wildlife habitat

questions. We also hope to detect historic trends and initiate predictions about how future environmental change and management activities may impact these processes. In addition to informing management, these predictions will identify monitoring indicators and approaches that would ultimately test, validate, and refine the predictions. Our ability to make predictions will be highly dependent on the availability and quality of the data. The three examples summarize the approaches to data analysis and list the general anticipated outcomes. These outcomes will be refined once the data evaluation has been completed and we have a better understanding of data quality as the basis for landscape-wide analysis.

Future Monitoring

Development and implementation of future monitoring of landscape change is our long-term goal for the GBILM pilot project. It would build upon the evaluation and analysis of existing data as well as the initial predictions derived from these analyses. Identification of data gaps and deficiencies will illuminate how current monitoring activities should be modified to address the deficiencies. Assessment of status and trend and the initial predictions of change will serve as the basis for revising monitoring questions, identifying indicators of landscape change, developing and testing protocols and analysis techniques, and determining proper sampling designs. We anticipate that new data collection would be required at this stage, potentially using a wide array of methods from field data collection to remote sensing applications. New data collection would be necessary for testing and validating monitoring protocols and ultimately in the implementation of monitoring landscape change over time.

While the USGS would play a central role in a long-term monitoring program, partnerships would be equally important for leveraging resources such as people, infrastructure, and funding toward collecting data and sustaining long-term commitment to landscape monitoring. We would envision an active USGS role in developing and testing monitoring protocols; providing training and technical support to partners; developing, managing and hosting the data in a web-accessible format; and conducting periodic analyses of monitoring data to determine landscape changes, adjust models and predictions, and add to our knowledge about landscape functions and processes.

Management Application of Results

The landscape analyses, predictions, and monitoring activities will be continuously evaluated against the initial management questions in order to maintain project focus. It will be essential to place a strong emphasis on developing and delivering products and decision support tools which are accessible and easy to understand so that they are readily applied in the management context. The resultant findings and analytical tools will aid managers in real-life applications such as setting priorities for fire management and habitat restoration, analyzing cumulative impacts as required by law, and understanding how local actions relate to landscape-scale matters such as species conservation and habitat fragmentation.

Example Projects Focused on Selected Drivers

Example 1: Water Extraction Project Summary

Title: Potential Phreatophytic Land Cover in the Great Basin and Relationship to Groundwater Withdrawals

Decisions related to water extraction present major challenges to land managers in the Great Basin. Land managers must be able to understand the systems they manage, how they are interconnected to one another, what changes, if any, could and do occur, and to what scale and ability they are able to manage the environments and processes around them. This project involves creating a map of potential

phreatophyte land cover of the Great Basin by categorizing evapotranspiration (ET) as a function of critical characteristics: geomorphology, vegetation species composition, elevation, and hydrology. Phreatophytic plants act as surface indicators of groundwater behavior and may serve as an indicator of areas impacted by groundwater drawdown. This map functions as a "proof-of-concept" given the regional data currently available—producing an assessment of data availability and accuracy within the Great Basin. Accordingly, this map will act as a first step toward developing baseline datasets of ecological conditions and effects of water extraction across the Great Basin. Next phases of this project will correlate mapped phreatophytic communities with hydrology data to identify areas potentially at risk from increasing demands on groundwater.

Key Management Questions Addressed by this Project

1. How will increased water extraction impact phreatophytes?
2. Can phreatophytic communities serve as an indicator of impacted groundwater systems?
3. How will water extraction impact these phreatophytic communities?

Study Questions

1. Where are potential phreatophytic communities, and what are their landscape characteristics?
2. What are the effects of aquifer drawdown on phreatophytic communities?
3. How do groundwater systems operate and what is the natural envelop of variability?
4. What is the impact of anthropogenic stressors on ground-water?
5. What are the areal relationships between ground-water extraction sites and impacted vegetation communities?

Project Approach

Phase 1 (Dec. 06-Feb. 07): Assessment using existing data

1. Collect data layers for geomorphology, SageMap, ReGAP vegetation species, elevation, hydrology, Great Basin boundary, roads, major cities, shaded relief
2. Coordinate data and establish GIS data layers
3. Develop and run spatial analysis model

Phase 2: Detecting and predicting change

1. Conduct analyses to detect temporal changes in water level within deep and shallow ground-water areas Generate a map (or series of maps) of change in the Great Basin's ground-water levels
2. Identify and map which ecosystems have already been impacted by ground-water extraction

Expected Products

Phase 1

1. Map of the potential phreatophytic land cover of the Great Basin.

Phase 2

1. Map (or series of maps) of change in the Great Basin's ground-water levels
2. Manuscript describing the use of phreatophytic communities as indicators of changes in ground-water levels and identifying areas at risk from increased demands on water supplies.

Example 2: Fire and Invasive Species Project Summary

Title: Fire Regimes in the Great Basin: Spatio-temporal Correlates and Future Scenarios

Decisions related to fire management and invasive species represent some of the major challenges facing land managers in the Great Basin. Land managers will never have the resources sufficient to actively manage all landscapes that may burn, and decisions must be made on how to allocate them most effectively. A key determinant in setting priorities revolves around understanding the degree to which fire regimes (size, frequency, seasonality, and cause) and associated vegetation conditions (physiognomy and proportion of non-native species) have been altered, and may be further altered in the future. This project will assess alterations to fire regimes and vegetation conditions across the Great Basin Ecoregion. This will provide the foundation for predicting changes into the future and developing monitoring protocols to detect landscape-scale changes and trends.

Key Management Question Addressed by this Project

How should land managers prioritize their efforts to manage fire regimes with the goal of retaining and restoring desired plant communities in the Great Basin?

Study Questions

1. What are the recent patterns of fire regime variables in the Great Basin?

2. How do these patterns relate to landscape characteristics and land-use patterns (biophysical properties, rainfall patterns, land-use history)

3. How do these patterns compare to estimates of historic conditions?

4. What evidence do these patterns and relationships provide for shifts in fire regimes caused by invasions by non-native plants, annual grasses in particular (i.e. the grass/fire cycle).

5. How may these patterns and relationships potentially change in the future given alternative climate regime scenarios?

6. What can land managers do now to manage current and potential future fire regimes and associated vegetation changes (e.g. relative to fuels management, fire suppression tactics, and emergency stabilization, rehabilitation, and restoration activities.

7. What is the best way to monitor changes in fire regimes and associated vegetation change over time?

Project Approach

Phase 1: Assessment based on existing data (Question #1-2)

1. Acquire/compile existing fire data for the Great Basin

2. Describe spatial patterns by producing simple maps

3. Describe temporal patterns by graphing distributions of fires among months and among years

4. Evaluate relationships between fire patterns and landscape data using various modeling techniques

Phase 2: Detecting and predicting change (Question #3-6)

1. Use data and results from Phase 1, existing fire regime assessments (e.g., LandFire, TNC Fire Learning Network, other publications), and professional opinion/observations to evaluate hypotheses related to the ways that invaders have altered fire regimes and how these relationships may change in the future.

Phase 3: Future monitoring (Question #7)

1. Using the results from phases 1 and 2, develop monitoring tools and a sampling design to monitor and assess changes in fire regimes and vegetation conditions over time.

2. Evaluate monitoring findings against predictions to refine/modify models and associated findings.

Expected Products

1. Maps/spatial data, manuscripts, trends and threats assessment for altered fire regimes among major vegetation types (at least related to annual grass invasions)

2. Land management recommendations

Example 3: Land Treatment Project Summary

Title: Assessment of Land Treatments to Understand Vegetation and Wildlife Habitat Trajectories in the Great Basin

In the Great Basin, state and federal land management agencies actively manipulate vegetation for purposes of livestock forage, wildlife habitat, invasive plant control, fuel reduction, post-fire stabilization and rehabilitation, and other needs. The spatial scale of land treatments vary from several acres to several thousand acres, but cumulatively represent a considerable portion of grassland and shrubland communities, particularly in the sagebrush biome. Information is needed to justify land treatment practices, improve implementation and monitoring of land treatments, evaluate the cumulative effects of land treatments on plant communities, wildlife habitats and habitat connectivity, and predict future conditions of vegetation and wildlife habitats across the Great Basin. This project is designed to assess the spatial characteristics (location, size, shape, landscape configuration), treatment characteristics (type of treatment, seed mixtures, application), and monitoring approaches of different land treatments to provide the foundation for developing monitoring strategies to determine the trends in vegetation and wildlife habitat conditions in the Great Basin. Monitoring data will ultimately guide adaptive land management for maintaining or improving wildlife habitats for sustainable populations.

Key Management Question Addressed by this Project

1. Are different land treatments moving vegetation communities toward desired conditions and how are these land treatments cumulatively influencing vegetation and wildlife habitats in the Great Basin?

2. How and where can land managers use land treatments for multiple objectives, including maintaining and restoring wildlife habitat and associated wildlife?

Study Questions

1. What land treatments have been conducted across the Great Basin since the 1950s?

2. What are the characteristics of these treatments, such as goals, when implemented, seed mixtures, applications, monitoring, etc?

3. Where are the treatments placed on the landscape?

4. How does the location, size, shape, and landscape configuration of land treatments influence wildlife habitat quantity, quality, and connectivity?

5. What changes in land treatment monitoring practices are needed to improve evaluation of treatment success and to assess trends in vegetation and habitat conditions into the future?

6. How can land treatment monitoring be used to understand effects of climate change and anthropogenic stressors in the Great Basin?

Project Approach

Phase 1: Assessment based on existing data (Questions 1-3)

1. Create a database suitable for storing relevant treatment information. This database will be designed to encourage addition of new treatments each year and to be useful to managers for tracking treatments.

2. Acquire and compile existing data on land treatments for the Great Basin from 1950 to present.

3. Describe spatial patterns at multiple scales by producing simple maps illustrating general land treatment type and year of implementation.

Phase 2: Detecting and predicting change (Questions 4)

1. Develop analysis tools and analyze data from phase 1 to develop predictive models that estimate effects of land treatments at various scales on wildlife habitats, particularly for sage grouse and other high profile species.

2. Coordinate and integrate these analyses with those being conducted for fire and invasive interactions across the Great Basin to assess cumulative effects and interactions on habitats.

3. Phase 3: Future Monitoring (Questions 5-6)

4. Develop guidelines and strategies for monitoring land treatments in the future.

5. Evaluate monitoring findings against predictions to refine/modify models and provide information on vegetation trends in the Great Basin.

Expected Products

1. Spatial data linked to treatment information in an accessible database

2. Maps of land treatments across broad areas of the Great Basin

3. White paper about monitoring approaches in the sagebrush biome as a result of monitoring workshop

4. Manuscript evaluating the effects of land treatments on sagebrush habitat connectivity

Partner Outreach and Involvement— Building a Long-Term Landscape Monitoring Program Partnership

Building partnerships with management agencies and other partners is essential for assuring the GBILM's relevance, usefulness, and long-term success. Toward this outcome, we will seek partner agency and stakeholder input throughout the project. Their perspectives are especially critical to keep the project focused on priority management questions and landscape-scale monitoring needs. The GBILM is primarily focused on Department of Interior (DOI) agencies, but other agencies and organizations are being contacted to identify landscape monitoring needs and questions, locate key data sets, and build ownership in the project's outcomes. These efforts build on a long record of collaborative research and monitoring in the Great Basin, which provides a solid foundation from which to build.

Partners as GBILM team members

Since the start of the project, the GBILM invited representatives from key partner agencies to participate. Due to interest, priority, and availability, individuals from BLM, NPS, and Environmental Protection Agency (EPA) have joined as team members in meetings, conference calls, and working group discussions. They have contributed invaluable insights about agency needs and issues and have

strengthened the quality of our current outcomes. Equally important, these team members serve as important liaisons to their broader organizational networks, and in doing so have broadly communicated the relevance of this effort and the need for even more participation.

Information Sharing

Initial efforts involved informing partners about the GBILM and gaining their insights as opportunities arose. Some of these efforts included meetings with BLM, NPS, and Fish and Wildlife Service (FWS) leadership at the local, state, and regional levels as well as presentations and discussions at partner meetings, such as the BLM National Inventory and Monitoring Team sagebrush monitoring meeting and the Great Basin Restoration Initiative core team meeting. The Great Basin Collaborative Workshop, attended by over 150 people from a wide range of research and management entities, afforded an excellent opportunity to showcase the GBILM and promote communication with partners. All team members will continue to discuss GBILM with colleagues as opportunities arise.

Proactive Outreach and Developing Partnerships: Priorities in FY07

During the first year of the project, we focused internally on developing the interdisciplinary team, conceptual modeling, and project planning and design. Now that this groundwork is completed, the priority is to reach out to many more partners. This outreach is intended to listen to partner perspectives and refine the pilot project in a manner that will meet the needs of resource management agencies. Our goal is to build buy-in and ownership that will sustain a long-term Great Basin landscape monitoring partnership

A sub-committee on partner outreach has developed a strategic plan which addresses: 1) goals; 2) key messages; 3) guiding principles; 4) key partners; and 5) outreach approaches, products, and actions.. Outreach and communication activities aim to communicate the goals and benefits of GBILM, but most importantly, to gather insights on *ecosystem drivers; management issues, needs, and questions; decision support tools; and the concepts of integrated landscape monitoring*. Listed below is an overview of activities planned for FY07.

1. Outreach activities will include

    *   Leadership meetings between GBILM and partner agency leaders to discuss purpose and needs, seek advice on project direction, and to establish leadership buy-in and support for the project. These meetings will primarily focus on line managers and key program leads in National, Regional, and State offices of the BLM, NPS, and FWS.

    *   Workshops with a cross-section of partner technical specialists and field personnel. For example, regional, state and field biologists, monitoring specialists, and planners will be invited to participate. These workshops will focus on validating, refining, and prioritizing ecosystem drivers, developing management and monitoring questions, and developing strategies to access and use existing data sets.

    *   Participation in existing agency meetings and workshops to inform partners of the GBILM and to gather feedback on ecosystem drivers, questions, and data access. Examples of such existing meetings include NPS Inventory and Monitoring Network meetings, BLM statewide resource specialist workshops, and meetings of the BLM National Inventory and Monitoring Team.

    *   Feedback to partner leadership to validate outcomes and direction, and adjust to address agency needs.

    *   Information dissemination will occur in several ways, including

- Launch and maintain a public web site for reference and product delivery

- Establish contact and mailing list for future involvement; send introductory mailer and link to web site

- Routine status reports to interested partners and collaborators

2. Further consideration will be given to creation of a stakeholder advisory group. The purpose of this group would be to maintain continuity over time, communicate progress to partners, gather advice throughout the project, and develop strategies to transfer project results for management applications. This possibility will be vetted through discussions associated with the meetings and workshops listed above.

Communicating Results and Establishing a Long-Term Program

Based on the communications and relationships developed over the next year, we envision continued outreach using the methods outlined above. Outreach goals will include:

1. Communicating results
2. Refining the project to meet partner needs
3. Establishing a long-term monitoring program through coordinated monitoring

Schedule and Products

The GBILM Pilot can be described in phases which generally track with fiscal years (Table 3). Each phase encompasses discrete steps in the landscape monitoring process, produces measurable products and outcomes on an annual basis, and supports documentation of the pilot process. Phase 1 was focused on developing an interdisciplinary team, developing broad goals for the pilot, and initiating conceptual modeling. Phase 2 focuses on completing conceptual models, conducting proactive outreach with partners, identifying and prioritizing drivers, and data mining and analysis on selected management questions to assess current conditions and trends. Phase 3 will build on Phase 2 efforts through continuation of pilot projects through the stage or predicting landscape change. During this phase, we would also consider pursuing additional management questions. Phase 4, dependent upon available funding, would focus on developing, testing, and implementing monitoring based on the first 3 phases of the project. Phase 4 is the stage in which partnerships will be essential to support additional funding and resources needed to implement new data collection and the long-term monitoring process.

Table 3. Project phases, focus, and products.

Phases and Period	Focus	Products
Phase 1- FY2006	• Develop pilot project strategy • Organize interdisciplinary team • Invite DOI agency representation • Develop understanding of capabilities • Identify agency monitoring needs • Define Great Basin boundary • Initiate conceptual modeling • Identify and prioritize drivers • Develop pilot focus on existing data	• Create internal website • Develop fact sheet • Great Basin pilot map • Draft conceptual models
Phase 2 - FY2007	• Proactive outreach to partners on drivers, questions, and data • Develop and initiate example projects to address questions on selected drivers • Mine, evaluate, analyze existing data for example projects • Conduct assessments of status and trends based on existing data for example projects • Refine conceptual model(s)	• Project Plan • Conceptual model report • Revised fact sheet • Partner outreach strategy • Public web site • Example project study plans • Map of phreatophytic vegetation • Compilation and evaluation of data sets on selected questions • Web-accessible data sets • Assessment reports from existing data
Phase 3 - FY2008 Last year of GBILM Pilot Project	• Predictions of landscape change based on historic trends and environmental factors Initiate development of monitoring approaches • Explore and pursue other management questions, as appropriate • Initiate cumulative impacts model	• Report of predictions for selected drivers • Analytical tools for managers to analyze management scenarios and set priorities • Study plans for additional management questions • Research proposals to fill identified data gaps
Phase 4 - FY2009 and beyond Requires funding commitment from USGS and partners to implement landscape monitoring	• Develop and test monitoring methods, protocols, and sampling designs on selected drivers (collect new data) • Implement long-term landscape monitoring on selected drivers • Expand predictions of landscape change • Expand to other drivers and management questions based on GBILM approach tested through example projects	• Monitoring methods, protocols, sampling designs • New data sets on web • Published, coordinated monitoring plan and protocols Analytical tools for managers to analyze management scenarios and set priorities • Study plans for additional management questions • Research proposals to fill identified data gaps

Appendixes

Appendix A. Management, Assessment, Prediction and Monitoring Questions

These questions represent brainstorming efforts at several meetings to generate management questions relevant to the priority system drivers. They were eventually refined and used to design pilot projects whose purpose is to illustrate the effectiveness of the GBILM approach to landscape monitoring. Questions that are not included in the pilot project descriptions are reported here.

Water Extraction

1. What are the current rates of water extraction across the Great Basin? How much water is there to be use? How has water use stratified surface rights versus groundwater rights across hydrographic areas?

2. What amount of water and at what rates can be extracted before surface biota is changed?

3. What methods could provide the data needed to provide answers that would satisfy scientists responsible for providing conclusions regarding degradation? What is the relevant time horizon?

4. How susceptible are valley floors (or portions of them) to change? What is the ecosystem/species envelope?

5. How do we identify the 'canary in the coal mine'?

6. How do we translate the water to the use people want to make for the water?

7. How much water can be extracted before we lose surface/ground-water-based resources (e.g., endemic spring snails, listed species)?

8. How much can be pumped before you lose the functionality of allotments?

9. What resources have been impacted from known extractions?

10. Is area vegetation a good proxy (derivative) fro groundwater resources? Example: if groundwater falls 2 inches, does is relate directly to changes in vegetation extent?

11. What are the criteria of interest? Example: should calculations of phreatophytic water use loss at ET change under greater water stress or monitor change in extent of phreatophytic vegetation?

12. How to determine relative effect of climate/recharge/extraction?

13. How can we limit the extraction of water?

14. When does drawdown reach the threshold level?

15. What is the most sensitive indicator? (water level? springs?)

16. What is the natural variability of groundwater resources before the system is stressed?

17. What are the impacts (tradeoffs) resulting from different levels (amounts/rates) of extractions? Are there legal mandates to establish thresholds (e.g., water rights, ESA)? Changing salinity reducing fertility of habitat, water quality?

18. What are the relative causes of groundwater fluctuations and how do we distinguish anthropogenic and non-anthropogenic causes?

19. What geographic area will show the effects of groundwater fluctuations?

20. What will be the effects of aquifer drawdown on ecosystems, esp. phreatophytic communities?

21. What processes cause the observed changes in spring discharge and groundwater levels?

Climate Change

1. What ecosystems or species will be extirpated by climate change?
2. What are the spatial and temporal patterns of climate?
3. How will biodiversity change as a result of climate change?
4. How will climate change affect hydrology (human use, availability, ecological cascading effects, and atmospheric transport systems)?
5. How will climate change affect invasive species and fire?
6. How will climate change affect resiliency of species and systems (including T&E species, focal species, and species of concern)?
7. How will climate change affect species distribution?
8. How will the rate and magnitude affect ecosystems and species?
9. How will climate change affect human use (agriculture, grazing, recreations)?
10. How will changes in human use that result from climate change affect ecosystems?
11. How will climate change alter phenology of plants and animals and their relationships?
12. How is climate change changing soil function?
13. How can regional climatology improve predictions of climate change (data gaps)?
14. How will climate change affect water supply?
15. Potential monitoring indicators: species assemblages across latitude and longitude; species distributions, phenology and life history characteristics; distribution, vigor, growth phenology of aspen and pikas; climate patterns; hydrology.

Fire and Invasives

1. What are the natural fire regimes without invasives?
2. Where are invasives impacting fire (increasing or decreasing relative to natural fire regimes)?
3. What are the densities of invasives that will lead to changes in fire regime?
4. What is the relative composition of native/invasive plants in habitat types across the Great Basin?
5. What habitat types are most impacted by invasive-impacted fire changes?
6. What is the size, location, and frequency of fires in the Great Basin?
7. What is the overlap of spatial extent of invasives relative to areas with changes in fire regimes?
8. Do invasive-driven fires promote new invasions?
9. What is the distribution of secondary invaders (e.g., knapweed) relative to areas where fire regimes have changed?
10. How will primary and secondary invasive species affect wildfire?
11. What are trend in the proportion of the Great Basin in the reference state?
12. What are trends in the proportion of burned lands in the reference state?
13. Where on the landscape are fire regimes changing? Where is it predicted to happen in the future?
14. How do activities of individual managers fit into a larger context?
15. Are higher levels of CO_2 increasing annual grasses?
16. Is the pattern of lightning strikes across the basin changing?

17. Is precipitation changing?
18. How does timing of grazing affect fire and invasives?
19. How does timing of grazing affect fuel levels?
20. What is the spatial extent of roads? How does this relate to the distribution of invasives?
21. What fuel levels result from various land treatments over time?

Appendix B. Team Members for the Great Basin Integrated Landscape Monitoring Pilot Project

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